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1. PURPOSE

The purpose of this calculation is to evaluate the effects of fission products loss on the reactivity of commercial pressurized water reactor (PWR) spent nuclear fuel (SNF) in 21 PWR waste packages (WPs) in the event of simultaneous fuel matrix degradation and assembly collapse. This is in support of the work outlined in Reference 1.

Referencing in this calculation refers to the input document number appearing in column 2a of the Document Input Reference Sheets (DIRS), Attachment I hereto.

2. METHOD

The Commercial PWR assembly design is based on the Babcock and Wilcox (B&W) 15 x 15 Mark B assembly (see Assumption 3.3). In this calculation, multiplication factor (k_{eff}) values are calculated for various degraded WP configurations using the Monte Carlo N-Particle transport code system version 4B2 (MCNP4B2; CSCI: 30033; Ref. 2). For each combination of enrichment and burnup evaluated, 18 axial fuel nodes are utilized to allow the effects of differences in burnup along the assembly length to be considered. Fuel region number densities used in this criticality evaluation were extracted from the MCNP cases from Reference 3 for a particular fuel node and decay time.

This calculation considers the waste package with uniform corrosion product distribution. Six fuel configurations, which are based on varying the rod pitch, will be considered for each combination of enrichment and burnup. Considering a conservative early breach of the waste package, this calculation assumes that the waste package will be full of uniform corrosion products at 10,000 years. For the first set of cases the reactivity of the waste package is evaluated for an intact fuel matrix at the nominal rod pitch with full fission product inventory. At 45,000 years the fuel matrix is considered completely collapsed such that the rods are touching and all the fission products released. Four intermediate cases are also evaluated at 14,000, 18,000, 25,000 and 35,000 years for which the rod pitch and fission product concentrations are linearly evaluated. The general geometry for these cases is presented in Figure 2-1. The reactivity of the collapsed cases is compared to the nominal case at the same time in life. The time in life of maximum increase of waste package reactivity is chosen to run the cases needed for the probability calculation. These cases cover all possible combinations of fission product loss and collapse fractions with which regression analyses were performed.

The MCNP cases of the three combinations of enrichment and burnup and all four decay times at original rod pitch were taken from the Tape Attachment of Reference 3. Input Cards 56 through 59 were modified to reflect original rod pitch between assemblies.

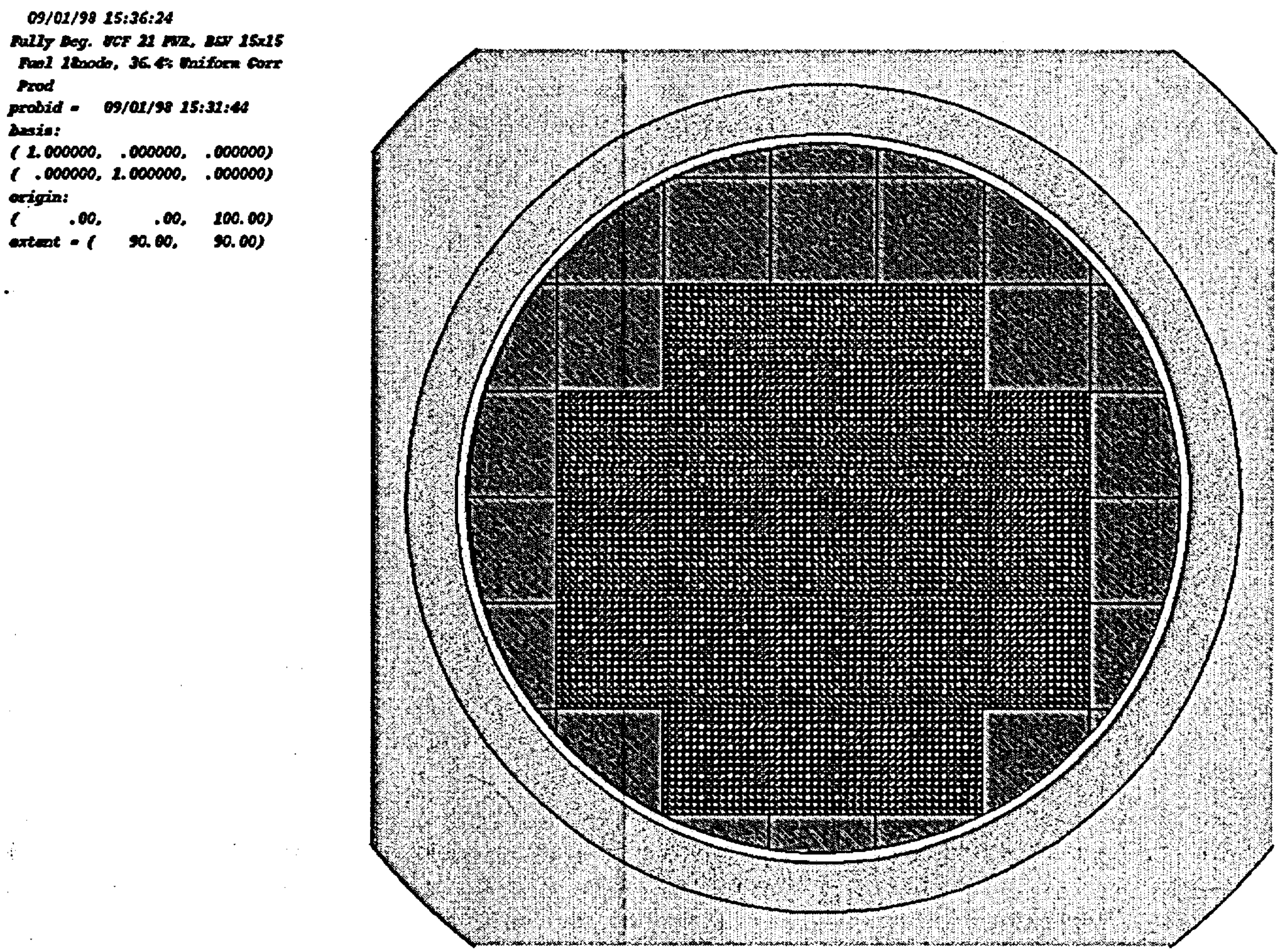

Figure 2-1. Degraded 21 PWR Fuel Waste Package with Uniform Corrosion Product Distribution

3. ASSUMPTIONS

3.1 Principal Isotope burnup credit is assumed to be an acceptable method to account for reduced reactivity of SNF in criticality evaluations. The basis for this assumption is Controlled Design Assumption Key 009 (Ref. 4). This assumption is used throughout Section 5.

3.2 For SNF, the list of "Principal Isotopes" previously established (Ref. 5, p. 3-26) for long-term criticality control was used. The 29 principal isotopes are shown in Table 3-1. The basis for this assumption is to maintain consistency with established precedent. This assumption is used throughout Section 5.

Table 3-1. Principal Long-Term Burnup Credit Isotopes

-	Mo-95	Tc-99	Ru-101	Rh-103
Ag-109	Nd-143	Nd-145	Sm-147	Sm-149
Sm-150	Sm-151	Sm-152	Eu-151	Eu-153
Gd-155	U-233	U-234	U-235	U-236
U-238	Np-237	Pu-238	Pu-239	Pu-240
Pu-241	Pu-242	Am-241	Am-242m	Am-243

3.3 It is assumed that B&W Mark B 15 x 15 fuel type is a typical PWR assembly designs to be used in this analysis. The basis for this assumption is that this assembly design is used in several existing PWRs. This assumption is used throughout Section 5.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 Software Approved for Quality Assurance (QA) Work

The calculation of k_{eff} of degraded internal WP configurations was performed with the MCNP computer code version 4B2 (CSCI: 30033; Ref. 2), which calculates k_{eff} for a variety of geometric configurations with neutron cross sections for elements and isotopes described in the Evaluated Nuclear Data File version B-V (ENDF-B/V). The calculations using the MCNP software were executed on a Hewlett-Packard workstation. The software qualification of the MCNP software version 4B2, including problems related to calculation of k_{eff} for fissile systems, is summarized in the Software Qualification Report for the Monte Carlo N-Particle code (Ref. 2). The MCNP evaluations performed for this calculation are fully within the range of the validation for the MCNP software versions used. Access to and use of the MCNP software for this analysis was granted by Software Configuration Management and performed in accordance with the appropriate procedures. Inputs and outputs for the MCNP software are included as Attachment II as described in Section 7.

4.2 Software Routines

Microsoft Excel 97, loaded on a Pentium II PC. This software was used to perform regression analyses for which the data are listed in Section 6.

4.3 Models

None used.

5. CALCULATION

5.1 Inputs

5.1.1 Spent Fuel Assembly Parameters

The fuel assembly upon which this calculation is based is the Babcock & Wilcox 15 x 15 Mark B fuel assembly. The mechanical parameters for this assembly type are shown in Table 5-1. This information represents actual B&W fuel assembly dimensions and is considered qualified data. Table 5-2 provides information on the fuel region node heights used in this calculation.

Table 5-1. Mechanical Parameters of B&W 15 × 15 Fuel Assembly
(Ref. 3, p. 9)

Parameter	Metric	Units
Fuel rods	208	/assembly
Fuel Rods on a lattice side	15	/side
Guide tubes	16	/assembly
Instrumentation tubes	1	/assembly
Total guide + instrument tubes	17	/assembly
Clad/tube material	Zirc-4	
Fuel pellet outer diameter (OD)	0.9398	cm
Fuel stack height	360.172	cm
Fuel assembly height	420.7	cm
Mass of U	464	kg
Mass of UO_2	526.38	kg
Percent of theoretical density	95	%
Fuel clad OD	1.0922	cm
Clad thickness	0.06731	cm
Fuel clad inner diameter (ID[a])	0.95758	cm
Fuel rod pitch	1.44272	cm
Guide tube OD	1.3462	cm
Guide tube thickness	0.04064	cm
Guide tube ID[a]	1.26492	cm
Instrumentation tube OD	1.25222	cm
Displaced Volume per Fuel Assembly	0.081	m^3

[a]The IDs are calculated by subtracting twice the thickness from the OD.

Table 5-2. Fuel Region Node Heights and Volumes
(Ref. 3, p. 10)

Node	Height (cm)	Volume (cm^3)[a]
1	17.7800	2565.4045
2 to 17	20.0025	2886.0801
18	22.3520	3225.0800

[a]Volumes calculated as $\pi(\text{Pellet OD})^2(\text{Height})/4$

5.1.2 Intact Waste Package Geometry Parameters

The intact waste package geometry parameters used in this calculation are listed in Table 5-3. This information is based on unqualified drawings or QAP-3-9 analyses and is therefore considered unqualified. Corrosion product volume information for the 21 PWR WP was calculated in Reference 6 and is summarized in Section 5.1.5. The corrosion product information is considered unqualified.

Table 5-3. Waste Package Dimensions
(Ref. 3, p. 10)

Component	21 PWR WP Dimensions (cm)	Material (Ref. 3, p. 10)
Outer barrier length (skirt edge to skirt edge)	533.50	A 516 Carbon Steel
Outer barrier skirt length (both ends)	22.50	
Outer barrier lid thickness	11.00	
Outer barrier inner radii	73.17	
Outer barrier outer radii	83.17	
Gap between inner and outer lids	3.00	Not Applicable
Inner barrier length (overall)	463.50	Alloy 22 (UNS N06022)
Inner barrier lid thickness	2.50	
Inner barrier inner radii	71.17	
Inner barrier outer radii	73.17	

5.1.3 Material Properties

Densities of non-fuel materials used in this analysis are listed in Table 5-4, which are considered unqualified:

Table 5-4. Densities of Non-Fuel Materials
(Ref. 3, p. 11)

Material	Density (kg/m^3)
A 516 Grade 70 carbon steel	7832
Inconel Alloy 625 (UNS N06625)	8442
Soddyite $(UO_2)_2(SiO_4)$:$2H_2O$	4700
Zircaloy-4	6560
Alloy 22 (Hastelloy Alloy C-22, UNS N06022)	8690
Water	1000

The atomic weights of isotopes are listed in Table 5-5 (Ref. 3, p. 11). Avogadro's Number [N_A]

= 0.602252×10^{24} (atoms/mole) (Ref. 3, p. 11). Chemical compositions of alloys used in this calculation are given in Table 5-6. This information is obtained from qualified QAP-3-9 analyses, or is considered established fact, and is therefore considered qualified.

Table 5-5. Atomic Weights (g/mole)
(Ref. 3, p. 12)

Isotope	MCNP ID#	Atomic Weight
B-10	5010.50C	10.0129388
B-11	5011.56C	11.0093053
Nat. O	not used	15.9994
O-16	8016.50C	15.994915
Nat. Fe	26000.55C	55.847
Mo-95	42095.50C	94.905839
Tc-99	43099.50C	98.90627501
Ru-101	44101.50C	100.905576
Rh-103	45103.50C	102.905511
Ag-109	47109.50C	108.904756
Nd-143	60143.50C	142.909779
Nd-145	60145.50C	144.912538
Sm-147	62147.50C	146.914867
Sm-149	62149.50C	148.91718
Sm-150	62150.50C	149.917276
Sm-151	62151.50C	150.919919
Sm-152	62152.50C	151.919756
Eu-151	63151.55C	150.919838
Eu-153	63153.55C	152.921242
Gd-155	64155.50C	154.922664
U-233	92233.50C	233.039522
U-234	92234.50C	234.040904
U-235	92235.50C	235.043915
U-236	92236.50C	236.045637
U-238	92238.50C	238.05077
Np-237	93237.55C	237.048056
Pu-238	94238.50C	238.049511
Pu-239	94239.55C	239.052146
Pu-240	94240.50C	240.053882
Pu-241	94241.50C	241.056737
Pu-242	94242.50C	242.058725
Am-241	95241.50C	241.056714
Am-242m	95242.50C	242.059502
Am-243	95243.50C	243.061367

Table 5-6. Chemical Compositions of WP and Fuel Assembly Alloys Modeled (Ref. 3, p. 13)

Material / Element	A 516 Grade 55Carbon Steel	Alloy 22 (Hastelloy Alloy C-22, UNS N06022)	Inconel Alloy 625 (UNS N06625)	Zircaloy-4
Fe	98.535%	3.000%	5.000%	0.200%
Cr	-	22.000%	21.500%	0.100%
Ni	-	56.000%	58.000%	-
Mn	0.900%	0.500%	0.500%	-
Mo	-	13.000%	9.000%	-
S	0.035%	-	0.015%	-
Si	0.275%	0.080%	0.500%	-
P	0.035%	-	0.015%	-
C	0.220%	0.010%	0.100%	-
O	-	-	-	0.120%
Co	-	2.060%	0.930%	-
W	-	3.000%	-	-
Ti	-	-	0.400%	-
Al	-	-	0.400%	-
V	-	0.350%	-	-
50%Nb+50%Ta	-	-	3.600%	-
Zr	-	-	-	98.180%
Sn	-	-	-	1.400%
TOTAL	100.00%	100.00%	100.00%	100.00%

5.1.4 Fuel Isotopic Concentrations

The fuel isotopic concentrations are the same as those in the MCNP cases from Reference 3 for 18 axial nodes per assembly. The following combinations of enrichment and burnup were utilized for this calculation: 3 wt% at 20 gigawatt days/ton (GWd/T), 4 wt% at 35 GWd/T and 4.5 wt% at 40 GWd/T.

5.1.5 Basket and Fuel Degradation Product Compositions

Reference 6 performed geochemistry calculations to determine the composition of the corrosion product mixture remaining in the 21 PWR waste package following complete basket degradation. Table 5-7 summarizes the concentrations of insoluble corrosion products that remain after the basket has completely degraded. Reference 6 indicates that this final composition remains fairly constant over the range of possible borated stainless steel degradation rates and drip rates. The moles/WP column is calculated by multiplying the moles/L H_2O column by 4,550 liters of H_2O, which is the amount of water considered to be in the WP in Reference 6 (equivalent to the void space available in a loaded WP with an undegraded basket).

Table 5-7. Corrosion Products Remaining Following Basket Degradation (Ref. 3, p. 14)

Basket Corrosion Product	Volume per WP (m^3)	moles/liter H_2O	moles/WP
Diaspore (AlOOH)	1.8392E-01	2.291	10424.05
Hematite (Fe_2O_3)	1.7707E+00	12.77	58103.5
Pyrolusite (MnO2)	2.7361E-02	0.35	1592.5
Ni_2SiO_4	3.0867E-02	0.1592	724.36
Nontronite-Ca ($Si_{3.7}Ca_{0.33}Al_{0.33}$ $Fe_2H_2O_{12}$)	1.2874E-02	0.0216	98.28
Nontronite-K ($Si_{3.7}K_{0.17}Al_{0.33}$ $Fe_2H_2O_{12}$)	5.6325E-04	0.0009151	4.163705
Nontronite-Mg ($Si_{3.7}Mg_{0.2}Al_{0.33}$ $Fe_2H_2O_{12}$)	8.9323E-03	0.01513	68.8415
Nontronite-Na ($Si_{3.7}Na_{0.33}Al_{0.33}$ $Fe_2H_2O_{12}$)	9.0407E-04	0.001504	6.8432
TOTAL	2.0362E+00		

Reference 6 also examined the effects that fuel degradation will have on the principal isotope inventory. Reference 6 examined two cases for both commercial and mixed oxide (MOX) PWR fuel: 1) fuel degradation concurrent with basket degradation, and 2) fuel degradation beginning after basket degradation is completed. The former case for the commercial PWR resulted in the greatest loss of principal isotopes due to lower pH conditions during degradation of the borated stainless steel and fuel. Table 5-8 summarizes the percentage of each principal isotope remaining at different times from the beginning of fuel degradation. Note that the geochemistry calculations of Reference 6, and thus the results in Table 5-8, do not account for the decay of the principle isotopes. Decay was accounted for by applying the reduced principle isotope concentrations for a given degradation time to a decay time that is equally offset from the point at which degradation began (i.e., if degradation is assumed to begin at 10,000 years, the principle isotope inventories at 12,000 years will be reduced as indicated for a degradation time of 2,000 years).

Table 5-8. Effects of Fuel Degradation on Principal Isotope Inventory (Ref. 3, p. 15)

Element	Fuel Degradation Time (yr)							
	2,000	4,000	8,000	15,000	25,000	35,000	90,000	240,000
U	100%	100%	100%	100%	99%	99%	96%	88%
Np	85%	70%	38%	0%	0%	0%	0%	0%
Pu	100%	100%	100%	100%	100%	100%	100%	100%
Am	0%	0%	0%	0%	0%	0%	0%	0%
Mo	0%	0%	0%	0%	0%	0%	0%	0%
Tc	0%	0%	0%	0%	0%	0%	0%	0%
Ru	100%	100%	100%	100%	100%	100%	100%	100%
Rh	100%	100%	100%	100%	100%	100%	100%	100%
Ag	87%	80%	67%	43%	12%	0%	0%	0%
Nd	99%	98%	97%	95%	95%	95%	95%	95%
Sm	80%	70%	46%	27%	26%	26%	24%	20%
Eu	82%	71%	46%	9%	8%	7%	2%	0%
Gd	56%	35%	14%	5%	5%	5%	5%	3%

5.2 Calculation of Number Densities for Degraded Basket Material

Based on the total volume of corrosion products remaining following full basket degradation (see Section 5.1.5), and the total volume contained within the inner barrier minus that occupied by the fuel assemblies (volume of the fuel rods), the corrosion products will occupy 36.4% of the interior void space of a 21 PWR WP. If the corrosion products settle to the bottom of the WP, the physical geometry of packed solids will result in a density that is less than theoretical. For example, the percent solid content noted for a tight packing of sand (Ref. 3, p. 15) is 58%. The porosity (the complement of the solids content) of tightly packed carbon steel tubesheet corrosion products that led to the denting of steam generator tubes at two Westinghouse plants was found to be between 7% and 25% (Ref. 3, p. 15). Since the oxides in the tubesheet were compressed to the point of denting the tube, and no such restriction of the oxides in the WP is expected, the tight packing of sand will be taken to be representative of that of iron oxide scale that has settled. At 58% dense packing, if all of the oxides settle to the bottom, they will completely cover the bottom three rows of assemblies, and cover more than 95% of the fourth row (93% or 14 rod rows of a B&W 15 x 15 Mark B assembly is conservatively used for this analysis). Number densities were calculated for the above corrosion product and water mixtures by dividing the moles of each element per WP (as indicated in Table 5-7) by the void space they occupied and multiplying by Avogadro's Number (0.602252×10^{24} atoms/mole). These calculations are performed in Reference 3.

5.3 Calculation of Number Densities for Fuel Region

The grams/assembly output for each time step was used to calculate the number density of each principal isotope (see Assumption 3.1). The number densities of the principal isotopes in the nominal cases for each combination of enrichment and burnup were calculated in Reference 3. The reduced number densities in the degraded matrix cases are simply calculated as a fractional change from the nominal.

5.4 MCNP Case Description

The purpose of this section is to describe the MCNP cases considered for the 21 PWR waste package design with intact fuel and fully degraded basket structures. In all of the cases, each B&W 15 x 15 fuel assembly is treated as a heterogeneous system with the fuel rods and control rod guide tubes and instrument tubes represented explicitly using the information contained in Section 5.1.1. The fuel assemblies are conservatively represented with water in the fuel rod gap region, and the instrument and guide tubes, even when surrounded by water/corrosion product mixtures, as there is no physical mechanism for getting basket corrosion products into these locations while the assembly remains intact. The composition and dimensions of the containment barriers are represented explicitly using the information in Section 5.1.2.

The MCNP cases will consider the evaluation of basket corrosion product composition discussed in Sections 5.1.5 and 5.2. The uniformly distributed corrosion product configurations is evaluated. Figure 2-1 shows the geometry details of the MCNP4B2 model for the 21 PWR WP with a fully degraded basket and uniformly distributed corrosion products for a range of rod pitch values of nominal spacing 1.44272, 1.40266, 1.3626, 1.2925, 1.19235 cm and touching rods in a square lattice 1.0922 cm which correspond to decay times of 10,000, 14,000, 18,000, 25,000, 35,000 to 45,000 years, respectively. The following combinations of enrichment and burnup will be evaluated: 3 wt% U-235 at 20 GWd/T, 4 wt% ^{235}U at 35 GWd/T, and 4.5 wt% U-235 at 40 GWd/T. The diameter of the guide tubes is slightly larger than the collapsed pitch such that a small portion of the clad is lost in the case representation, which has no effect on the system reactivity. The pitch/decay time combination that yields the highest increase in waste package reactivity will be used to perform the cases for the probability calculations. The three combinations of burnup and enrichment at the most reactive time in life will be used to evaluate the waste package reactivity at all pitch values and fission loss fractions such that a total of 108 cases will be run.

6. RESULTS

Table 6-1 lists k_{eff} and standard deviation (σ) values for the cases used to determine the pitch/decay time combination that yields the highest increase in reactivity. The cases at 25,000 years with a pitch of 0.64625 cm yield the highest reactivity increase. Table 6-2 lists the k_{eff} values for the cases for the three combinations of enrichment and burnup at 25,000 years decay for all possible fission product loss (FPL) fractions and pitch combinations. Using the data in Table 6-2, a regression analysis was performed to evaluate Δk as a function of pitch and fission product loss for each combination of enrichment and burnup as listed in Table 6-3. The average of the three regression fits was evaluated and is listed in Table 6-3. The average energy of neutron causing fission (AENCF) is also included is the aforementioned tables. The fission product loss fraction used for some of the cases in Table 6-1 was rounded off, thus some of the k_{eff} values are slightly different, but within the standard deviation, than the similar cases in Table 6-2.

The results reported in Section 6 are based on unqualified data and must be verified prior to use in quality affecting activities or for use in analyses affecting procurement, construction, or fabrication.

Table 6-1. Reactivity Evaluation of Simultaneous Matrix Degradation and Assembly Collapse

Enrichment (wt% U-235)	Burnup (GWd/T)	Degradation Time (yr)	k_{eff} at 0% FPL, 0.72136 cm Pitch	2σ	AENCF (MeV)	File Name	Pitch/2 (cm)	FPL (%)	k_{eff}	2σ	AENCF (MeV)	File Name	Δk
4.50	40	10000.00	0.88223	0.00280	0.24889	nu4540bo	0.72136	0.00	0.88223	0.00280	0.24889	nu4540bo	0.00000
4.50	40	14000.00	0.88501	0.00306	0.24519	nu4540do	0.70133	11.43	0.88350	0.00406	0.25979	ru4540do	-0.00151
4.50	40	18000.00	0.88686	0.00304	0.24384	nu4540eo	0.68130	22.86	0.8969	0.00282	0.27004	ru4540eo	0.01004
4.50	40	25000.00	0.88833	0.00298	0.24020	nu4540fo	0.64625	42.86	0.89452	0.00326	0.29605	ru4540fo	0.00619
4.50	40	35000.00	0.88679	0.00288	0.23862	nu4540go	0.59617	71.43	0.88692	0.00338	0.34405	ru4540go	0.00013
4.50	40	45000.00	0.88184	0.00304	0.23639	nu4540ho	0.54610	100.00	0.85289	0.00288	0.42668	ru4540ho	-0.02895
4.00	35	10000.00	0.87101	0.00280	0.25086	nu4035bo	0.72136	0.00	0.87101	0.00280	0.25086	nu4035bo	0.00000
4.00	35	14000.00	0.87427	0.00298	0.24869	nu4035do	0.70133	11.43	0.87579	0.00350	0.26230	ru4035do	0.00152
4.00	35	18000.00	0.88241	0.00248	0.24455	nu4035eo	0.68130	22.86	0.88549	0.00358	0.27133	ru4035eo	0.00308
4.00	35	25000.00	0.87934	0.00262	0.24200	nu4035fo	0.64625	42.86	0.88624	0.00378	0.30015	ru4035fo	0.00690
4.00	35	35000.00	0.88034	0.00264	0.24020	nu4035go	0.59617	71.43	0.8753	0.00242	0.34949	ru4035go	-0.00504
4.00	35	45000.00	0.87555	0.00256	0.23921	nu4035ho	0.54610	100.00	0.83905	0.00284	0.43296	ru4035ho	-0.03650
3.00	20	10000.00	0.89948	0.00216	0.24555	nu3020bo	0.72136	0.00	0.89948	0.00216	0.24555	nu3020bo	0.00000
3.00	20	14000.00	0.90098	0.00214	0.24475	nu3020do	0.70133	11.43	0.90478	0.00282	0.25669	ru3020do	0.00380
3.00	20	18000.00	0.90076	0.00204	0.24230	nu3020eo	0.68130	22.86	0.91007	0.00300	0.26662	ru3020eo	0.00931
3.00	20	25000.00	0.90340	0.00200	0.23949	nu3020fo	0.64625	42.86	0.90911	0.00242	0.29314	ru3020fo	0.00571
3.00	20	35000.00	0.89775	0.00198	0.23664	nu3020go	0.59617	71.43	0.89636	0.00318	0.34591	ru3020go	-0.00139
3.00	20	45000.00	0.89408	0.00416	0.23735	nu3020ho	0.54610	100.00	0.84148	0.00286	0.43276	ru3020ho	-0.05260

Table 6-2. Reactivity Evaluation of Simultaneous Matrix Degradation and Assembly Collapse

Case	Enrichment (wt% U-235)	Burnup (GWd/T)	k_{eff}	2σ	AENCF (MeV)	FPL (%)	Collapse (%)	Δk
3020aao:	3.00	20	0.90219	0.00258	0.24083	0	0.00	0
3020abo:	3.00	20	0.89775	0.00278	0.25303	0	11.43	-0.00444
3020aco:	3.00	20	0.88834	0.00244	0.27114	0	22.86	-0.01385
3020ado:	3.00	20	0.87788	0.00244	0.30266	0	42.86	-0.02431
3020aeo:	3.00	20	0.83745	0.0027	0.37118	0	71.43	-0.06474
3020afo:	3.00	20	0.75927	0.00258	0.48549	0	100.00	-0.14292
3020bao:	3.00	20	0.90728	0.00274	0.23759	11.43	0.00	0.00509
3020bbo:	3.00	20	0.90542	0.00266	0.25147	11.43	11.43	0.00323
3020bco:	3.00	20	0.89843	0.00242	0.26771	11.43	22.86	-0.00376
3020bdo:	3.00	20	0.88706	0.0029	0.30091	11.43	42.86	-0.01513
3020beo:	3.00	20	0.84516	0.00348	0.36867	11.43	71.43	-0.05703
3020bfo:	3.00	20	0.76537	0.00296	0.48038	11.43	100.00	-0.13682
3020cao:	3.00	20	0.9151	0.0023	0.23607	22.86	0.00	0.01291
3020cbo:	3.00	20	0.91158	0.00196	0.24890	22.86	11.43	0.00939
3020cco:	3.00	20	0.90993	0.00228	0.26387	22.86	22.86	0.00774
3020cdo:	3.00	20	0.89484	0.00288	0.29725	22.86	42.86	-0.00735
3020ceo:	3.00	20	0.85174	0.00276	0.36887	22.86	71.43	-0.05045
3020cfo:	3.00	20	0.7732	0.00298	0.47534	22.86	100.00	-0.12899
3020dao:	3.00	20	0.9227	0.00296	0.23543	42.9	0.00	0.02051
3020dbo:	3.00	20	0.92491	0.00274	0.24612	42.9	11.43	0.02272
3020dco:	3.00	20	0.921	0.00266	0.26262	42.9	22.86	0.01881
3020ddo:	3.00	20	0.90996	0.00244	0.29257	42.9	42.86	0.00777
3020deo:	3.00	20	0.86818	0.00268	0.36036	42.9	71.43	-0.03401
3020dfo:	3.00	20	0.78912	0.00270	0.46849	42.9	100.00	-0.11307
3020eao:	3.00	20	0.94986	0.00256	0.22653	71.43	0.00	0.04767
3020ebo:	3.00	20	0.94823	0.00294	0.24076	71.43	11.43	0.04604
3020eco:	3.00	20	0.94693	0.00288	0.25248	71.43	22.86	0.04474
3020edo:	3.00	20	0.93497	0.0027	0.28711	71.43	42.86	0.03278
3020eeo:	3.00	20	0.893	0.00252	0.34980	71.43	71.43	-0.00919
3020efo:	3.00	20	0.81187	0.00254	0.45823	71.43	100.00	-0.09032
3020fao:	3.00	20	0.97601	0.00258	0.22135	100	0.00	0.07382
3020fbo:	3.00	20	0.97392	0.00276	0.23494	100	11.43	0.07173
3020fco:	3.00	20	0.97359	0.00306	0.24792	100	22.86	0.0714
3020fdo:	3.00	20	0.96038	0.00312	0.27983	100	42.86	0.05819
3020feo:	3.00	20	0.92103	0.00274	0.34198	100	71.43	0.01884
3020ffo:	3.00	20	0.83886	0.00284	0.44057	100	100.00	-0.06333
4035aao:	4.00	35	0.87586	0.00348	0.24338	0	0.00	0
4035abo:	4.00	35	0.87492	0.00302	0.25518	0	11.43	-0.00094

Table 6-2. Reactivity Evaluation of Simultaneous Matrix Degradation and Assembly Collapse

Case	Enrichment (wt% U-235)	Burnup (GWd/T)	k_{eff}	2σ	AENCF (MeV)	FPL (%)	Collapse (%)	Δk
4035aco:	4.00	35	0.86666	0.00354	0.27289	0	22.86	-0.0092
4035ado:	4.00	35	0.84407	0.00338	0.31336	0	42.86	-0.03179
4035aeo:	4.00	35	0.80006	0.00384	0.38530	0	71.43	-0.0758
4035afo:	4.00	35	0.72499	0.00332	0.50077	0	100.00	-0.15087
4035bao:	4.00	35	0.88524	0.00292	0.24189	11.43	0.00	0.00938
4035bbo:	4.00	35	0.88189	0.00332	0.25820	11.43	11.43	0.00603
4035bco:	4.00	35	0.86819	0.00328	0.27697	11.43	22.86	-0.00767
4035bdo:	4.00	35	0.84986	0.00272	0.31202	11.43	42.86	-0.026
4035beo:	4.00	35	0.81253	0.00328	0.38307	11.43	71.43	-0.06333
4035bfo:	4.00	35	0.73908	0.00266	0.49194	11.43	100.00	-0.13678
4035cao:	4.00	35	0.89574	0.00322	0.24138	22.86	0.00	0.01988
4035cbo:	4.00	35	0.89537	0.00294	0.25430	22.86	11.43	0.01951
4035cco:	4.00	35	0.88416	0.00288	0.27345	22.86	22.86	0.0083
4035cdo:	4.00	35	0.86883	0.0033	0.30655	22.86	42.86	-0.00703
4035ceo:	4.00	35	0.82394	0.00344	0.37389	22.86	71.43	-0.05192
4035cfo:	4.00	35	0.74846	0.0032	0.49118	22.86	100.00	-0.1274
4035dao:	4.00	35	0.91255	0.00284	0.23662	42.9	0.00	0.03669
4035dbo:	4.00	35	0.91582	0.00286	0.24829	42.9	11.43	0.03996
4035dco:	4.00	35	0.90648	0.00258	0.26527	42.9	22.86	0.03062
4035ddo:	4.00	35	0.87908	0.00286	0.30382	42.9	42.86	0.00322
4035deo:	4.00	35	0.84197	0.00294	0.36573	42.9	71.43	-0.03389
4035dfo:	4.00	35	0.76791	0.00304	0.48303	42.9	100.00	-0.10795
4035eao:	4.00	35	0.94328	0.00278	0.22864	71.43	0.00	0.06742
4035ebo:	4.00	35	0.94075	0.0031	0.24208	71.43	11.43	0.06489
4035eco:	4.00	35	0.93187	0.00288	0.25936	71.43	22.86	0.05601
4035edo:	4.00	35	0.9196	0.00274	0.29138	71.43	42.86	0.04374
4035eeo:	4.00	35	0.87468	0.00266	0.35608	71.43	71.43	-0.00118
4035efo:	4.00	35	0.79494	0.00256	0.46596	71.43	100.00	-0.08092
4035fao:	4.00	35	0.97949	0.0026	0.22015	100	0.00	0.10363
4035fbo:	4.00	35	0.9754	0.00302	0.23309	100	11.43	0.09954
4035fco:	4.00	35	0.97445	0.00244	0.24663	100	22.86	0.09859
4035fdo:	4.00	35	0.96187	0.00276	0.27614	100	42.86	0.08601
4035feo:	4.00	35	0.91677	0.00332	0.34297	100	71.43	0.04091
4035ffo:	4.00	35	0.83295	0.00362	0.44631	100	100.00	-0.04291
4540aao:	4.50	40	0.88322	0.0043	0.24202	0	0.00	0
4540abo:	4.50	40	0.87585	0.00328	0.25514	0	11.43	-0.00737
4540aco:	4.50	40	0.86737	0.00376	0.27197	0	22.86	-0.01585
4540ado:	4.50	40	0.8448	0.00372	0.31176	0	42.86	-0.03842

Table 6-2. Reactivity Evaluation of Simultaneous Matrix Degradation and Assembly Collapse

Case	Enrichment (wt% U-235)	Burnup (GWd/T)	k_{eff}	2σ	AENCF (MeV)	FPL (%)	Collapse (%)	Δk
4540aeo:	4.50	40	0.80341	0.0034	0.38390	0	71.43	-0.07981
4540afo:	4.50	40	0.72776	0.00348	0.49870	0	100.00	-0.15546
4540bao:	4.50	40	0.8904	0.00316	0.24048	11.43	0.00	0.00718
4540bbo:	4.50	40	0.88711	0.00372	0.25625	11.43	11.43	0.00389
4540bco:	4.50	40	0.88601	0.0034	0.26774	11.43	22.86	0.00279
4540bdo:	4.50	40	0.85572	0.00352	0.30874	11.43	42.86	-0.0275
4540beo:	4.50	40	0.8124	0.00398	0.37953	11.43	71.43	-0.07082
4540bfo:	4.50	40	0.74004	0.00328	0.49027	11.43	100.00	-0.14318
4540cao:	4.50	40	0.90395	0.00406	0.23400	22.86	0.00	0.02073
4540cbo:	4.50	40	0.90054	0.00292	0.24939	22.86	11.43	0.01732
4540cco:	4.50	40	0.89134	0.00316	0.26629	22.86	22.86	0.00812
4540cdo:	4.50	40	0.87262	0.00302	0.30071	22.86	42.86	-0.0106
4540ceo:	4.50	40	0.82563	0.00308	0.37229	22.86	71.43	-0.05759
4540cfo:	4.50	40	0.7498	0.00348	0.48670	22.86	100.00	-0.13342
4540dao:	4.50	40	0.91819	0.00290	0.23320	42.9	0.00	0.03497
4540dbo:	4.50	40	0.91553	0.00330	0.24811	42.9	11.43	0.03231
4540dco:	4.50	40	0.913	0.00358	0.26363	42.9	22.86	0.02978
4540ddo:	4.50	40	0.89357	0.00354	0.29618	42.9	42.86	0.01035
4540deo:	4.50	40	0.84152	0.00324	0.36605	42.9	71.43	-0.0417
4540dfo:	4.50	40	0.76986	0.00346	0.47709	42.9	100.00	-0.11336
4540eao:	4.50	40	0.95989	0.00364	0.22425	71.43	0.00	0.07667
4540ebo:	4.50	40	0.95205	0.00286	0.24043	71.43	11.43	0.06883
4540eco:	4.50	40	0.94811	0.00306	0.25294	71.43	22.86	0.06489
4540edo:	4.50	40	0.92473	0.00292	0.28479	71.43	42.86	0.04151
4540eeo:	4.50	40	0.8831	0.0027	0.35275	71.43	71.43	-0.00012
4540efo:	4.50	40	0.8013	0.00336	0.45987	71.43	100.00	-0.08192
4540fao:	4.50	40	0.99227	0.0024	0.21681	100	0.00	0.10905
4540fbo:	4.50	40	0.99148	0.00222	0.22990	100	11.43	0.10826
4540fco:	4.50	40	0.9887	0.0028	0.24262	100	22.86	0.10548
4540fdo:	4.50	40	0.96699	0.0027	0.27722	100	42.86	0.08377
4540feo:	4.50	40	0.92047	0.00316	0.33757	100	71.43	0.03725
4540ffo:	4.50	40	0.84063	0.00258	0.44114	100	100.00	-0.04259

Table 6-3. Regression Results of Δk as a Function of Fission Product Loss and Assembly Collapse

Enrichment (wt% U-235)	Burnup (GWd/T)	Intercept	% FPL	% Collapse
3.0	20	0	0.00090428	-0.0012381
4.0	35	0	0.0011859	-0.0013417
4.5	40	0	0.0012478	-0.0014189
Average		0	0.0011127	-0.0013329

7. ATTACHMENTS

Attachments to this document are listed in Table 7-1 below.

Table 7-1. List of Attachments

Attachment Number	Description
I	Document Input Reference Sheets (DIRS)
II	CD-ROM Containing the Input and Output Files for the MCNP Calculations.

The following supporting documents listed in Table 7-2 are in electronic form on a CD. Each file is identified by its name, size (in bytes), the date and time of last access. Note that for files transferred from the Hewlett-Packard to the Personal Computer, the date and time will reflect the time of transfer. The actual date and time of run completion can be found in the file.

Table 7-2. List of Files in Attachment II

File Name	Date	Time	Size (bytes)
nu3020b	08/24/99	02:48 PM	44,372
nu3020bo	08/24/99	02:49 PM	699,267
nu3020d	08/24/99	02:49 PM	43,835
nu3020do	08/24/99	02:49 PM	692,466
nu3020e	08/24/99	02:49 PM	42,718
nu3020eo	08/24/99	02:49 PM	678,408
nu3020f	08/24/99	02:49 PM	42,720
nu3020fo	08/24/99	02:49 PM	678,328
nu3020g	08/24/99	02:49 PM	42,707
nu3020go	08/24/99	02:49 PM	678,508
nu3020h	08/24/99	02:49 PM	42,710
nu3020ho	08/24/99	02:49 PM	678,369
nu4035b	08/24/99	02:49 PM	44,394
nu4035bo	08/24/99	02:49 PM	699,206
nu4035d	08/24/99	02:49 PM	43,832
nu4035do	08/24/99	02:49 PM	692,553
nu4035e	08/24/99	02:49 PM	42,675
nu4035eo	08/24/99	02:49 PM	678,321
nu4035f	08/24/99	02:49 PM	42,712
nu4035fo	08/24/99	02:49 PM	678,529
nu4035g	08/24/99	02:49 PM	42,728
nu4035go	08/24/99	02:49 PM	678,707
nu4035h	08/24/99	02:49 PM	42,706
nu4035ho	08/24/99	02:49 PM	678,360
nu4540b	08/24/99	02:49 PM	44,377
nu4540bo	08/24/99	02:49 PM	699,206
nu4540d	08/24/99	02:49 PM	43,856
nu4540do	08/24/99	02:49 PM	692,508

File Name	Date	Time	Size (bytes)
nu4540e	08/24/99	02:49 PM	42,735
nu4540eo	08/24/99	02:49 PM	678,622
nu4540f	08/24/99	02:49 PM	42,732
nu4540fo	08/24/99	02:50 PM	678,538
nu4540g	08/24/99	02:50 PM	42,747
nu4540go	08/24/99	02:50 PM	678,408
nu4540h	08/24/99	02:50 PM	42,759
nu4540ho	08/24/99	02:50 PM	678,408
ru3020d	08/24/99	03:26 PM	45,313
ru3020do	08/24/99	03:26 PM	624,498
ru3020e	08/24/99	03:33 PM	44,125
ru3020eo	08/24/99	03:33 PM	609,476
ru3020f	08/24/99	03:33 PM	44,121
ru3020fo	08/24/99	03:33 PM	608,428
ru3020g	08/24/99	03:33 PM	44,121
ru3020go	08/24/99	03:33 PM	606,903
ru3020h	08/24/99	03:27 PM	34,020
ru3020ho	08/24/99	03:27 PM	488,177
ru4035d	08/24/99	03:27 PM	45,313
ru4035do	08/24/99	03:27 PM	624,443
ru4035e	08/24/99	03:33 PM	44,125
ru4035eo	08/24/99	03:33 PM	609,517
ru4035f	08/24/99	03:33 PM	44,121
ru4035fo	08/24/99	03:34 PM	608,474
ru4035g	08/24/99	03:34 PM	44,121
ru4035go	08/24/99	03:34 PM	606,908
ru4035h	08/24/99	03:27 PM	33,372
ru4035ho	08/24/99	03:27 PM	488,259
ru4540d	08/24/99	03:27 PM	44,557
ru4540do	08/24/99	03:27 PM	624,924
ru4540e	08/24/99	03:34 PM	43,388
ru4540eo	08/24/99	03:34 PM	609,610
ru4540f	08/24/99	03:34 PM	43,383
ru4540fo	08/24/99	03:34 PM	608,494
ru4540g	08/24/99	03:34 PM	43,383
ru4540go	08/24/99	03:34 PM	606,903
ru4540h	08/24/99	03:28 PM	33,211
ru4540ho	08/24/99	03:28 PM	488,223
3020aa	08/24/99	03:01 PM	42,719
3020aao	08/24/99	03:01 PM	611,299
3020ab	08/24/99	03:01 PM	42,907
3020abo	08/24/99	03:01 PM	610,527
3020ac	08/24/99	03:01 PM	42,907
3020aco	08/24/99	03:01 PM	609,569
3020ad	08/24/99	03:01 PM	42,903
3020ado	08/24/99	03:01 PM	608,569
3020ae	08/24/99	03:01 PM	42,903
3020aeo	08/24/99	03:01 PM	607,132
3020af	08/24/99	03:01 PM	42,903
3020afo	08/24/99	03:01 PM	605,249

File Name	Date	Time	Size (bytes)
3020ba	08/24/99	03:01 PM	43,938
3020bao	08/24/99	03:01 PM	611,490
3020bb	08/24/99	03:01 PM	44,125
3020bbo	08/24/99	03:02 PM	610,393
3020bc	08/24/99	03:02 PM	44,125
3020bco	08/24/99	03:02 PM	609,007
3020bd	08/24/99	03:02 PM	44,121
3020bdo	08/24/99	03:02 PM	607,957
3020be	08/24/99	03:02 PM	44,121
3020beo	08/24/99	03:02 PM	607,004
3020bf	08/24/99	03:02 PM	44,121
3020bfo	08/24/99	03:02 PM	605,203
3020ca	08/24/99	03:02 PM	43,937
3020cao	08/24/99	03:02 PM	611,253
3020cb	08/24/99	03:02 PM	44,125
3020cbo	08/24/99	03:02 PM	610,494
3020cc	08/24/99	03:02 PM	44,125
3020cco	08/24/99	03:02 PM	609,524
3020cd	08/24/99	03:02 PM	44,121
3020cdo	08/24/99	03:02 PM	608,610
3020ce	08/24/99	03:02 PM	44,121
3020ceo	08/24/99	03:02 PM	606,957
3020cf	08/24/99	03:02 PM	44,121
3020cfo	08/24/99	03:02 PM	605,298
3020da	08/24/99	03:31 PM	44,121
3020dao	08/24/99	03:31 PM	608,952
3020db	08/24/99	03:31 PM	44,121
3020dbo	08/24/99	03:32 PM	610,440
3020dc	08/24/99	03:32 PM	44,121
3020dco	08/24/99	03:32 PM	609,523
3020dd	08/24/99	03:32 PM	44,119
3020ddo	08/24/99	03:32 PM	608,476
3020de	08/24/99	03:32 PM	44,119
3020deo	08/24/99	03:32 PM	606,855
3020df	08/24/99	03:32 PM	44,119
3020dfo	08/24/99	03:32 PM	605,202
3020ea	08/24/99	03:03 PM	43,937
3020eao	08/24/99	03:03 PM	611,353
3020eb	08/24/99	03:03 PM	44,125
3020ebo	08/24/99	03:03 PM	610,541
3020ec	08/24/99	03:03 PM	44,125
3020eco	08/24/99	03:03 PM	609,624
3020ed	08/24/99	03:03 PM	44,121
3020edo	08/24/99	03:03 PM	608,475
3020ee	08/24/99	03:03 PM	44,121
3020eeo	08/24/99	03:03 PM	606,951
3020ef	08/24/99	03:03 PM	44,121
3020efo	08/24/99	03:03 PM	605,202
3020fa	08/24/99	03:03 PM	33,839
3020fao	08/24/99	03:03 PM	494,127

File Name	Date	Time	Size (bytes)
3020fb	08/24/99	03:03 PM	34,027
3020fbo	08/24/99	03:04 PM	493,679
3020fc	08/24/99	03:04 PM	34,027
3020fco	08/24/99	03:04 PM	492,667
3020fd	08/24/99	03:04 PM	34,023
3020fdo	08/24/99	03:04 PM	491,714
3020fe	08/24/99	03:04 PM	34,024
3020feo	08/24/99	03:04 PM	490,135
3020ff	08/24/99	03:04 PM	34,023
3020ffo	08/24/99	03:04 PM	488,129
4035aa	08/24/99	03:04 PM	42,711
4035aao	08/24/99	03:04 PM	611,340
4035ab	08/24/99	03:04 PM	42,899
4035abo	08/24/99	03:04 PM	610,480
4035ac	08/24/99	03:04 PM	42,899
4035aco	08/24/99	03:04 PM	609,736
4035ad	08/24/99	03:04 PM	42,895
4035ado	08/24/99	03:04 PM	608,567
4035ae	08/24/99	03:04 PM	42,895
4035aeo	08/24/99	03:04 PM	606,948
4035af	08/24/99	03:04 PM	42,895
4035afo	08/24/99	03:05 PM	605,342
4035ba	08/24/99	03:05 PM	43,937
4035bao	08/24/99	03:05 PM	611,318
4035bb	08/24/99	03:05 PM	44,125
4035bbo	08/24/99	03:05 PM	610,338
4035bc	08/24/99	03:05 PM	44,125
4035bco	08/24/99	03:05 PM	609,521
4035bd	08/24/99	03:05 PM	44,121
4035bdo	08/24/99	03:05 PM	608,521
4035be	08/24/99	03:05 PM	44,121
4035beo	08/24/99	03:05 PM	606,902
4035bf	08/24/99	03:05 PM	44,121
4035bfo	08/24/99	03:05 PM	605,243
4035ca	08/24/99	03:05 PM	43,937
4035cao	08/24/99	03:05 PM	611,245
4035cb	08/24/99	03:05 PM	44,125
4035cbo	08/24/99	03:05 PM	610,345
4035cc	08/24/99	03:05 PM	44,125
4035cco	08/24/99	03:05 PM	609,617
4035cd	08/24/99	03:06 PM	44,121
4035cdo	08/24/99	03:06 PM	608,420
4035ce	08/24/99	03:06 PM	44,121
4035ceo	08/24/99	03:06 PM	606,902
4035cf	08/24/99	03:06 PM	44,121
4035cfo	08/24/99	03:06 PM	605,250
4035da	08/24/99	03:32 PM	44,120
4035dao	08/24/99	03:32 PM	608,944
4035db	08/24/99	03:32 PM	44,121
4035dbo	08/24/99	03:32 PM	610,440

File Name	Date	Time	Size (bytes)
4035dc	08/24/99	03:32 PM	44,121
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4035dd	08/24/99	03:32 PM	44,119
4035ddo	08/24/99	03:32 PM	608,476
4035de	08/24/99	03:32 PM	44,119
4035deo	08/24/99	03:32 PM	606,997
4035df	08/24/99	03:32 PM	44,119
4035dfo	08/24/99	03:32 PM	605,203
4035ea	08/24/99	03:06 PM	43,937
4035eao	08/24/99	03:06 PM	611,483
4035eb	08/24/99	03:06 PM	44,125
4035ebo	08/24/99	03:06 PM	610,445
4035ec	08/24/99	03:06 PM	44,125
4035eco	08/24/99	03:06 PM	609,516
4035ed	08/24/99	03:06 PM	44,121
4035edo	08/24/99	03:07 PM	608,475
4035ee	08/24/99	03:07 PM	44,121
4035eeo	08/24/99	03:07 PM	606,950
4035ef	08/24/99	03:07 PM	44,121
4035efo	08/24/99	03:07 PM	605,239
4035fa	08/24/99	03:07 PM	33,839
4035fao	08/24/99	03:07 PM	494,256
4035fb	08/24/99	03:07 PM	34,027
4035fbo	08/24/99	03:07 PM	493,626
4035fc	08/24/99	03:07 PM	34,027
4035fco	08/24/99	03:07 PM	492,714
4035fd	08/24/99	03:07 PM	34,023
4035fdo	08/24/99	03:07 PM	491,666
4035fe	08/24/99	03:07 PM	34,023
4035feo	08/24/99	03:07 PM	490,094
4035ff	08/24/99	03:07 PM	34,023
4035ffo	08/24/99	03:07 PM	488,081
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4540ab	08/24/99	03:07 PM	42,919
4540abo	08/24/99	03:07 PM	610,696
4540ac	08/24/99	03:07 PM	42,919
4540aco	08/24/99	03:07 PM	609,688
4540ad	08/24/99	03:07 PM	42,911
4540ado	08/24/99	03:07 PM	608,615
4540ae	08/24/99	03:07 PM	42,911
4540aeo	08/24/99	03:07 PM	607,043
4540af	08/24/99	03:07 PM	42,911
4540afo	08/24/99	03:07 PM	605,342
4540ba	08/24/99	03:07 PM	43,937
4540bao	08/24/99	03:08 PM	611,251
4540bb	08/24/99	03:08 PM	44,125
4540bbo	08/24/99	03:08 PM	610,290
4540bc	08/24/99	03:08 PM	44,125
4540bco	08/24/99	03:08 PM	609,474

File Name	Date	Time	Size (bytes)
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4540be	08/24/99	03:08 PM	44,117
4540beo	08/24/99	03:08 PM	606,902
4540bf	08/24/99	03:08 PM	44,117
4540bfo	08/24/99	03:08 PM	605,249
4540ca	08/24/99	03:08 PM	43,937
4540cao	08/24/99	03:08 PM	611,341
4540cb	08/24/99	03:08 PM	44,125
4540cbo	08/24/99	03:08 PM	610,438
4540cc	08/24/99	03:08 PM	44,125
4540cco	08/24/99	03:08 PM	609,529
4540cd	08/24/99	03:08 PM	44,117
4540cdo	08/24/99	03:08 PM	608,474
4540ce	08/24/99	03:08 PM	44,117
4540ceo	08/24/99	03:08 PM	606,902
4540cf	08/24/99	03:08 PM	44,117
4540cfo	08/24/99	03:08 PM	605,051
4540da	08/24/99	03:32 PM	43,385
4540dao	08/24/99	03:33 PM	609,113
4540db	08/24/99	03:33 PM	43,385
4540dbo	08/24/99	03:33 PM	610,391
4540dc	08/24/99	03:33 PM	43,385
4540dco	08/24/99	03:33 PM	609,569
4540dd	08/24/99	03:33 PM	43,383
4540ddo	08/24/99	03:33 PM	608,426
4540de	08/24/99	03:33 PM	43,383
4540deo	08/24/99	03:33 PM	606,956
4540df	08/24/99	03:33 PM	43,383
4540dfo	08/24/99	03:33 PM	605,185
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4540eao	08/24/99	03:08 PM	611,346
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4540ebo	08/24/99	03:08 PM	610,493
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4540eco	08/24/99	03:09 PM	609,738
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4540edo	08/24/99	03:09 PM	608,427
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4540eeo	08/24/99	03:09 PM	606,908
4540ef	08/24/99	03:09 PM	44,117
4540efo	08/24/99	03:09 PM	605,152
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4540fao	08/24/99	03:09 PM	493,661
4540fb	08/24/99	03:09 PM	34,027
4540fbo	08/24/99	03:09 PM	493,319
4540fc	08/24/99	03:09 PM	34,027
4540fco	08/24/99	03:09 PM	492,655
4540fd	08/24/99	03:09 PM	34,019
4540fdo	08/24/99	03:09 PM	491,714

File Name	Date	Time	Size (bytes)
4540fe	08/24/99	03:09 PM	34,019
4540feo	08/24/99	03:09 PM	490,041
4540ff	08/24/99	03:09 PM	34,019
4540ffo	08/24/99	03:09 PM	488,122

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SHEET

1. Document Identifier No./Rev.:	Change:	Title:
CAL-EBS-NU-000002 REV 00	N/A	Simulating the Effect on Criticality of Simultaneous Matrix Degradation and Assembly Collapse for the 21 PWR Waste Package

Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
2a 1	CRWMS M&O 1999. *DP for Simulating the Effect on Criticality of Simultaneous Matrix Degradation and Assembly Collapse*. TDP-EBS-NU-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990824.0146.	Entire	N/A	1	Development plan; Reference, not an input	N/A	N/A	N/A	N/A
2	CRWMS M&O 1998. *Software Qualification Report for MCNP V4B2*. 30033-2003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980622.0637.	Entire	N/A	2 4.1	SQR; Reference, not an input	N/A	N/A	N/A	N/A

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CAL-EBS-NU-000002 REV 00	N/A	Simulating the Effect on Criticality of Simultaneous Matrix Degradation and Assembly Collapse for the 21 PWR Waste Package

Input Document							8. TBV Due To		
	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	Unqual.	From Uncontrolled Source	Un-confirmed
3	CRWMS M&O 1998. *Supplemental Criticality Evaluation for Degraded Internal Configurations of a 21 PWR Waste Package*. BBA000000-01717-0210-00022 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980918.0086.	Entire	TBV-3376	2 3 4 5	MCNP cases calculation of number densities Based on unqualified data.	3	Yes	N/A	N/A
4	CRWMS M&O 1998. *Controlled Design Assumptions Document*. B00000000-01717-4600-00032 REV 05. Las Vegas, Nevada: CRWMS ACC: M&O. MOL.19980804.0481.	Key 009	TBV-3377	3.1	Basis for an assumption	3	Yes	N/A	N/A

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DOCUMENT INPUT REFERENCE SHEET

1. Document Identifier No./Rev.:	Change:	Title:
CAL-EBS-NU-000002 REV 00	N/A	Simulating the Effect on Criticality of Simultaneous Matrix Degradation and Assembly Collapse for the 21 PWR Waste Package

Input Document							8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	Unqual.	From Uncontrolled Source	Un-confirmed
5	CRWMS M&O 1997. *Disposal Criticality Analysis Methodology Technical Report*. B00000000-01717-5705-00020 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980108.0700.	p. 3-26	TBV-3378	3.2	Basis for an assumption	3	Yes	N/A	N/A
6	CRWMS M&O 1998. *EQ6 Calculations for Chemical Degradation of PWR LEU and PWR MOX Spent Fuel Waste Packages*. BBA000000-01717-0210-00009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980701.0483.	5	TBV-3379	5.1.5	Basket and Fuel Degradation Product Compositions Based on unqualified data.	3	Yes	N/A	N/A